NACA

RESEARCH MEMORANDUM

SUPPLEMENTARY WIND-TUNNEL INVESTIGATION OF

THE STABILITY OF THE JETTISONABLE NOSE

SECTION OF THE X-2 AIRPLANE

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
August 12, 1949

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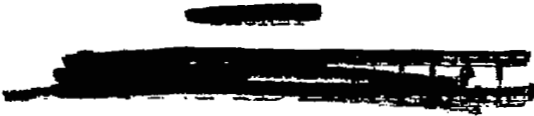
SECTION OF THE X-2 AIRPLANE

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SUMMARY

A supplementary stability investigation has been conducted in the Langley 20-foot free-spinning tunnel on a $\frac{1}{15}$-scale model of the jettisonable nose section of the Bell X-2 airplane. In a previous investigation, the size of flat triangular fins required for nose stabilization was determined. The present investigation was conducted in an attempt to find a fin configuration that would stabilize the nose section with less fin area and to determine the size fin required if they were curved to permit retraction against the fuselage in normal flight. Brief tests were also made to determine the effect of various bridle-line arrangements on the effectiveness of a parachute attached to the rear of the nose section in preventing rotations of the nose during free fall.

The results of the investigation indicated that the fin area necessary for stabilization could be approximately halved by changing their configuration to that recommended herein and that the nose section could be stabilized by curved fins of this configuration. It was also indicated that the bridle-line arrangement used in attaching a stabilizing parachute to the rear of a nose section did not appreciably alter the effectiveness of the parachute in preventing rotations of the nose section during free fall.

INTRODUCTION

The NACA is conducting a general investigation of methods of safe pilot escape from high-speed aircraft. One method that has been proposed for the X-2 airplane and for several other recent designs is to jettison the nose of the airplane at a breakoff station immediately rearward of the pilot. It is planned that after the nose has been jettisoned and its speed has decreased, the pilot will leave the nose section and descend with his parachute.

As pointed out in reference 1, low–speed tests of a $\frac{1}{15}$–scale model
of the X–2 jettisonable nose section in the Langley 20–foot free–
spinning tunnel indicated that the airplane nose section in its
original configuration is inherently unstable and that if jettisoned
in this condition would undergo rotations which would cause acceler-
ations dangerous to the pilot. Recent results (data unpublished)
obtained with a model of a jettisonable nose section of another airplane
have indicated that the rotary motion of an unstable nose jettisoned at
high speed may not necessarily be similar to that indicated at low
speed, but that even if the nose does not rotate it will tend to trim
away from a nose–first flight attitude which may cause decelerations
dangerous to the pilot. It appears that if the nose could be made to
continue flying in a nose–first stable attitude after being jettisoned,
the deceleration would not be excessive and, in addition, would act on
the pilot's body in the direction (transverse) in which human tolerance
to acceleration is greatest.

Test data which indicate that flat fins of triangular shape could
be used to stabilize the X–2 nose section are presented in reference 1.
In an attempt to reduce the size of stabilizing fin necessary and to
simplify the problem of fin retraction, the present supplementary
investigation was made. It was indicated by the contractor that the
center of gravity could not be moved forward as recommended in
reference 1, but that the fins tested during this investigation could
extend behind the nose breakoff station whereas those of reference 1
did not. The present investigation also included brief tests to
determine the effect of various bridle–line arrangements on the
effectiveness of a parachute attached to the rear of the nose section
in preventing rotations of the nose section during free fall when no
fins were installed on the nose section.

SYMBOLS

L   length of nose section (center–of–gravity location is
                    expressed as a percentage of this length from the
                    front end of the nose section)

X, Y, Z   longitudinal, lateral, and normal body axes, respectively,
                    through center of gravity of nose

I_X, I_Y, I_Z full–scale values of moments of inertia about X, Y,
                    and Z body axis, respectively, slug–feet^2

ρ air density, slugs per cubic foot

V airspeed, feet per second

C_{D_p} drag coefficient of parachute $\left(\dfrac{\text{Drag}}{\frac{1}{2}\rho V^2 S_p} \right)$

S_p projected area of fully inflated parachute, square feet

APPARATUS AND METHODS

Model

The tests were made with a $\dfrac{1}{15}$—scale model of the jettisonable nose section of the Bell X-2 airplane, the same model used for the tests reported in reference 1. Photographs of the model are presented as figure 1 and a drawing of the model is shown in figure 2. The various stabilizing fins tested on the model are included in figure 2.

For the parachute tests, a $4\frac{1}{4}$—inch—diameter hemispherical—type parachute made from cloth having a porosity of 400 cubic feet of air flow per square foot per minute measured at a pressure of 1/2 inch of water was used. When open in the tunnel air stream, the parachute was stable and alined itself approximately with the direction of the air stream. The drag coefficient of the parachute C_{D_p} was 1.0 based on its projected area. Figure 3 is a drawing of the model showing the various methods of attaching the parachute and the nomenclature and dimensioning system used for the parachute tests.

Wind Tunnel and Testing Technique

The model tests were performed in the Langley 20-foot free—spinning tunnel, the operation of which is, in general, similar to that described in reference 2 for the Langley 15—foot free—spinning tunnel, except that models are now launched into the vertically rising air stream by hand rather than from a spindle. A photograph which shows the test section of the Langley 20-foot free—spinning tunnel with a typical spin—tunnel airplane model spinning in the tunnel is shown as figure 4.

The testing technique used in determining fin size required for stabilization was essentially the same as that of reference 1. For the parachute tests, the model was held in the vertically rising air

stream until the parachute inflated and was then released to float in
the test section while a motion-picture record was made of its behavior.
The angles that the model made with the relative wind (angle of attack
and angle of yaw) were read from this record and used as a basis of
comparison for the various arrangements tested.

Test Condition and Precision

The mass characteristics of the $\frac{1}{15}$-scale model of the X-2 jetti-
sonable nose are presented in table I. The fin arrangements tested on
the model are indicated in figure 2. The various arrangements for
parachute stabilization are indicated in figure 3.

The accuracy of measuring the weight and mass distribution of the
model is believed to be similar to that of reference 1 and within the
following limits:

Weight, percent . . . . ± 1
Center-of-gravity location, inches . . . . ± 0.01
Moments of inertia, slug-feet^2:
  I_X . . . . ± 10
  I_Y . . . . ± 12
  I_Z . . . . ± 5

RESULTS AND DISCUSSION

Stabilization by Fins

A tabulation of the fin-stabilization test results obtained during
the investigation is presented in table II.

The requirement that the fins be capable of retraction by folding
against the sides of the fuselage imposes a definite limitation upon
their spanwise dimension since they should not overlap when retracted.
It was necessary, therefore, in the present investigation to use fins
with an aspect ratio of the order of 0.4. Tests reported in refer-
ence 1 for the X-2 nose and for another nose indicated that the use of
fins with aspect ratios as low as 0.8 and 0.4, respectively, was not
desirable because they caused each nose to assume an attitude with its
X-axis horizontal and to roll rapidly about this axis. A major differ-
ence between the low-aspect-ratio fins of reference 1 and those of the
present investigation, however, is that the present fins are farther
rearward of the center of gravity because of their extension behind
the breakoff station, and it was felt that this would prevent the nose

from trimming horizontally so that it would have no opportunity to set up a rolling rotation. This theory was borne out during the present investigation in which the nose section showed no tendency to trim horizontally and roll. As a further check on this reasoning, the fins with an aspect ratio of 0.8 used on the X-2 model in reference 1 were reinstalled at a more rearward location so as to extend partly behind the breakoff station, and the model in this condition damped any applied rotation and descended stably nose down; a similar result was obtained with the other nose section mentioned in reference 1 with fins of aspect ratio 0.4 installed so as to extend behind the breakoff station.

The results of tests in which curved fins of three sizes (arrangements A, B, and C in fig. 2) were added to the model indicate that when the largest of the three sizes (fins C) were used, the model damped any applied rotation and descended stably nose down. The motion-picture strips in figure 5 show the model with curved fins C attached as it damped an applied rotation about the Z body axis and descended stably nose down. From the results of references 1 and 3, it appears likely that if the nose center-of-gravity position could be moved forward, correspondingly smaller fins could be used for stabilization.

The motion-picture strips in figure 6 show the behavior of the model when curved fins B, which were not large enough to stabilize the nose, were installed.

The flat fins of reference 1 were of triangular shape and did not extend beyond the breakoff station, and they therefore can not be directly compared to the curved fins of the present investigation. In an attempt to compare the relative effectiveness of curved and flat fins, brief additional tests were made using flat fins (arrangements D and E in fig. 2) attached in radial planes at the same positions on the nose section as were the curved fins. Although the results of these tests indicated that slightly larger fins might be required if they were curved, subsequent investigations have revealed that the difference was primarily due to the ensuing decrease in projected area in the radial plane because the curved fins were bent away from the straight fin positions. Tests on another model of a jettisonable nose section (data unpublished) indicated that if curved fins are installed so that they have projected areas, in the plane of the flat fins, equal to the flat-fin areas, they are equally as effective.

Stabilization by Parachutes

A tabulation of the test results obtained when a parachute was attached to the model without fins is contained in table III. For all bridle arrangements tested, it was found that when the model with parachute attached was released to float in the vertically rising air

stream the nose section descended with negligible rotation or oscillation and trimmed at some relatively small angle with the air stream. A comparison of the various arrangements is made on the basis of the trim angle of the nose section. The three- and four-line bridles caused the nose section to trim at smaller angles of attack and yaw than the one- and two-line bridles. In a brief test made to determine the effect of a misadjusted bridle, two bridle lines of a four-line arrangement were shortened so that the model was deflected 10° from a vertical attitude when hung up by the extension line. The misadjusted bridle increased the angle that the nose section made with the relative wind but again no rotations were introduced.

Based on the four-line bridle test with the open parachute and on an additional test made with the parachute reefed to give only one-half its original drag, the angles that the nose made with the relative wind during the present tests agree quite closely with data taken in the Wright Field vertical wind tunnel (reported in reference 4) which show the variation of the angle of attack of the nose with parachute drag.

CONCLUSIONS

Based on the results of supplementary tests made in the Langley 20-foot free-spinning tunnel on a $\frac{1}{15}$-scale model of the jettisonable nose section of the Bell X-2 airplane, the following conclusions are drawn:

1. The nose section can be stabilized by the addition of curved fins of suitable size.

2. The bridle—line arrangement used in attaching a stabilizing parachute to the nose section does not appreciably alter the effectiveness of the parachute in preventing rotations of the nose section during free fall.

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REFERENCES

1. Scher, Stanley H., and Goodwin, Roscoe H.: Wind—Tunnel Investigation of the Stability of the Jettisonable Nose Section of the XS—2 Airplane. NACA RM L8I14, 1948.

2. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free—Spinning Wind Tunnel. NACA Rep. 557, 1936.

3. Scher, Stanley H.: Wind—Tunnel Investigation of the Stability of Jettisoned Nose Sections of the D—558 Airplane — Phases I and II. NACA RM L7K10, 1948.

4. Doty, Paul R., and Deis, Frank R.: Tests of $\frac{3}{8}$—Scale Model XS—2 Airplane Jettisonable Nose Section and Parachute Assembly in the 12—Foot Vertical Wind Tunnel. Memo. Rep. Ser. No. TSEAC14—672—4—2, Air Materiel Command, Army Air Forces, Eng. Div., Nov. 3, 1947.

TABLE I.— COMPARISON OF THE MASS CHARACTERISTICS OF

THE $\frac{1}{15}$—SCALE MODEL AND THE FULL-SCALE JETTISONABLE

NOSE SECTION OF THE BELL X-2 AIRPLANE

Center-of-gravity location	Weight (lb)	Moments of inertia about center of gravity		
		I_X (slug-ft^2)	I_Y (slug-ft^2)	I_Z (slug-ft^2)
[1]Model values				
Normal position (0.670L)	978	36	170	158
Airplane values				
Normal position (0.670L)	982.8	30.8	184.3	163.1

[1]Model values are presented in terms of full-scale values.

TABLE II.— RESULTS OF SUPPLEMENTARY FIN–STABILIZATION TESTS ON

THE $\frac{1}{15}$—SCALE MODEL OF THE JETTISONABLE NOSE SECTION OF THE

X–2 AIRPLANE IN THE LANGLEY 20–FOOT FREE–SPINNING TUNNEL

Fin arrangement (see fig. 2)	Behavior of free–falling model
Curved fins	
A	Model sometimes tumbled and sometimes oscillated through an arc of ±90° from a nose–down attitude
B	Model sometimes oscillated through an arc of ±90° from a nose–down attitude, sometimes descended in a stable nose–down attitude, and once took up a rapid rotation about a vertical wind axis while rolling about its X–axis
C	Model damped any applied rotation and descended in a stable nose–down attitude
Flat fins	
D	Model damped any applied rotation and descended in a stable nose–down attitude
E	Model sometimes oscillated through an arc of ±90° from a nose–down attitude and sometimes took up a rotation about a vertical wind axis

TABLE III.— RESULTS OF PARACHUTE STABILIZATION TESTS ON

THE $\frac{1}{15}$—SCALE MODEL OF THE JETTISONABLE NOSE SECTION

OF THE X—2 AIRPLANE IN THE LANGLEY

20—FOOT FREE—SPINNING TUNNEL

| Type of bridle (see fig. 3)	Rate of descent (fps full—scale)	Angle of attack of nose (deg)	Angle of yaw of nose (deg)
Four—line	224	−5	4
Three—line	224	−3	3
Two—line	224	−8	13
One—line	224	−8	10
[1]Four—line	224	−17	4
[2]Four—line	283	−11	13

[1]Two of the bridle lines were shortened so that the model hung at
   an angle of attack of −10° when supported by extension line.
[2]Parachute reefed with drawstring around canopy so as to give one—
   half its original drag.
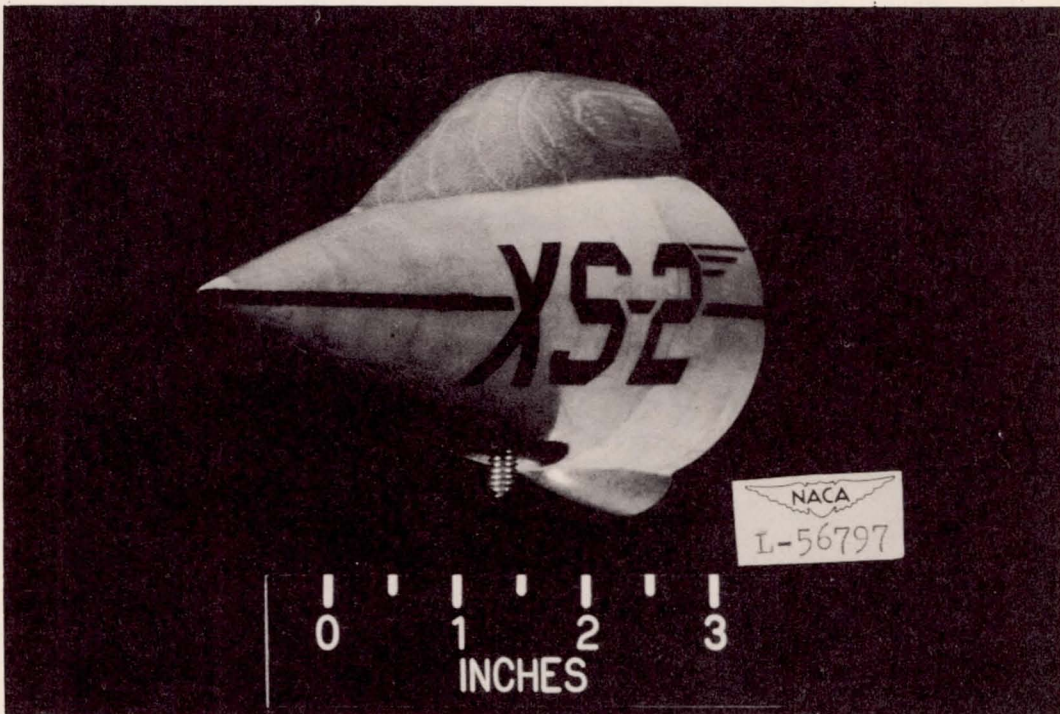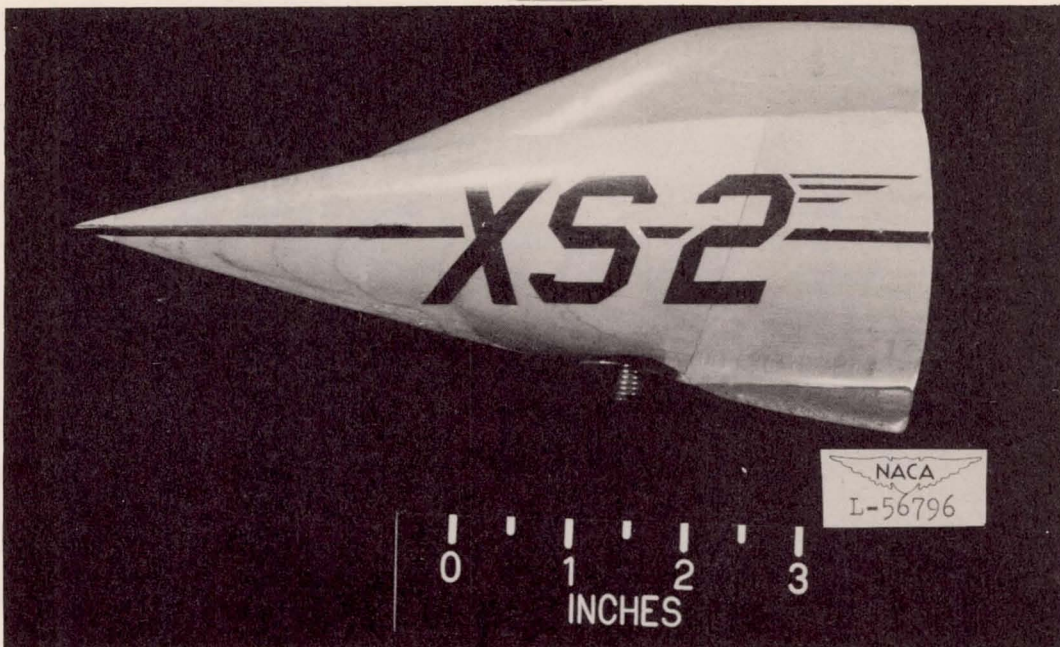
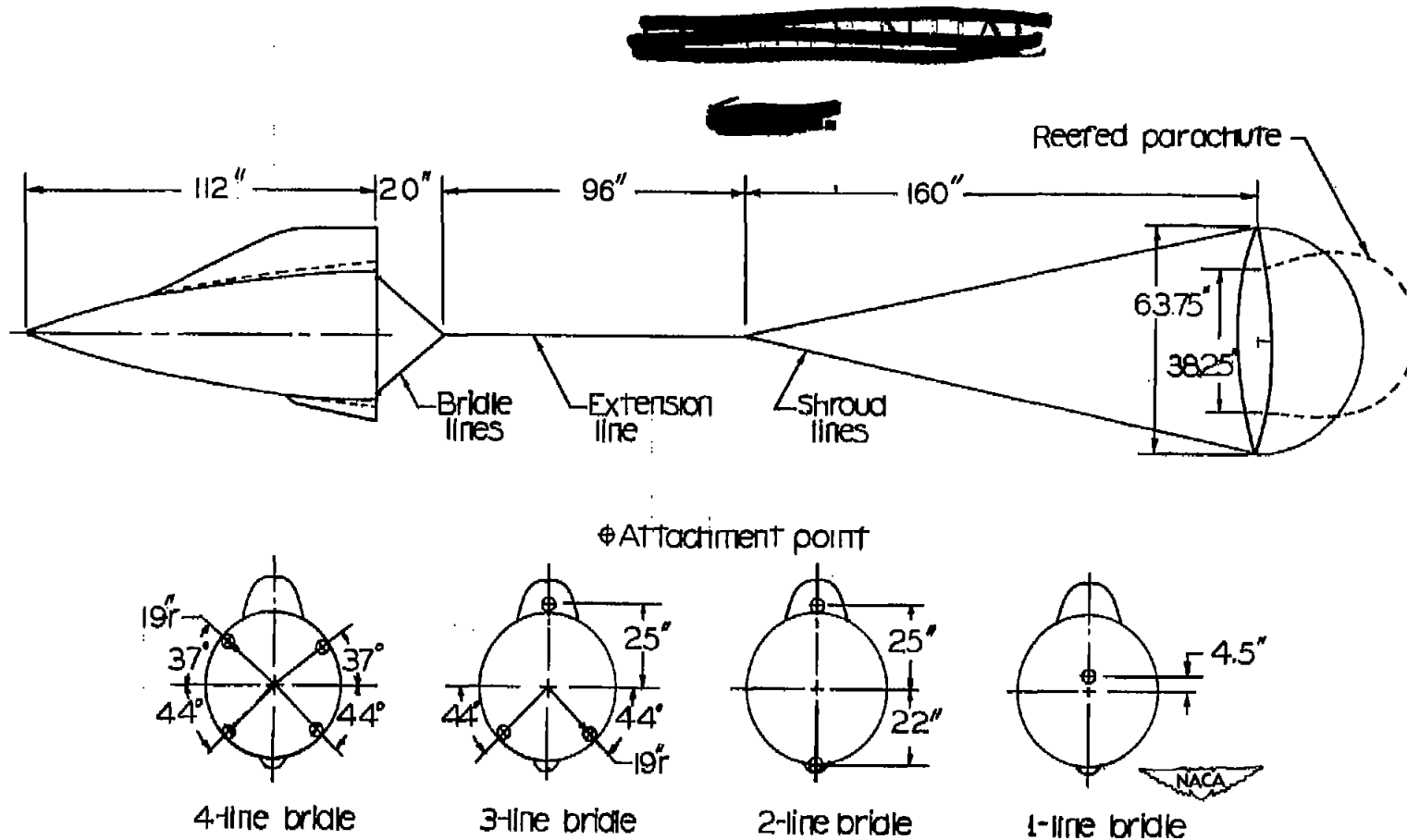Figure 1.- Photographs of the $\frac{1}{15}$-scale model of the jettisonable nose section of the Bell X-2 airplane tested in the Langley 20-foot free-spinning tunnel.
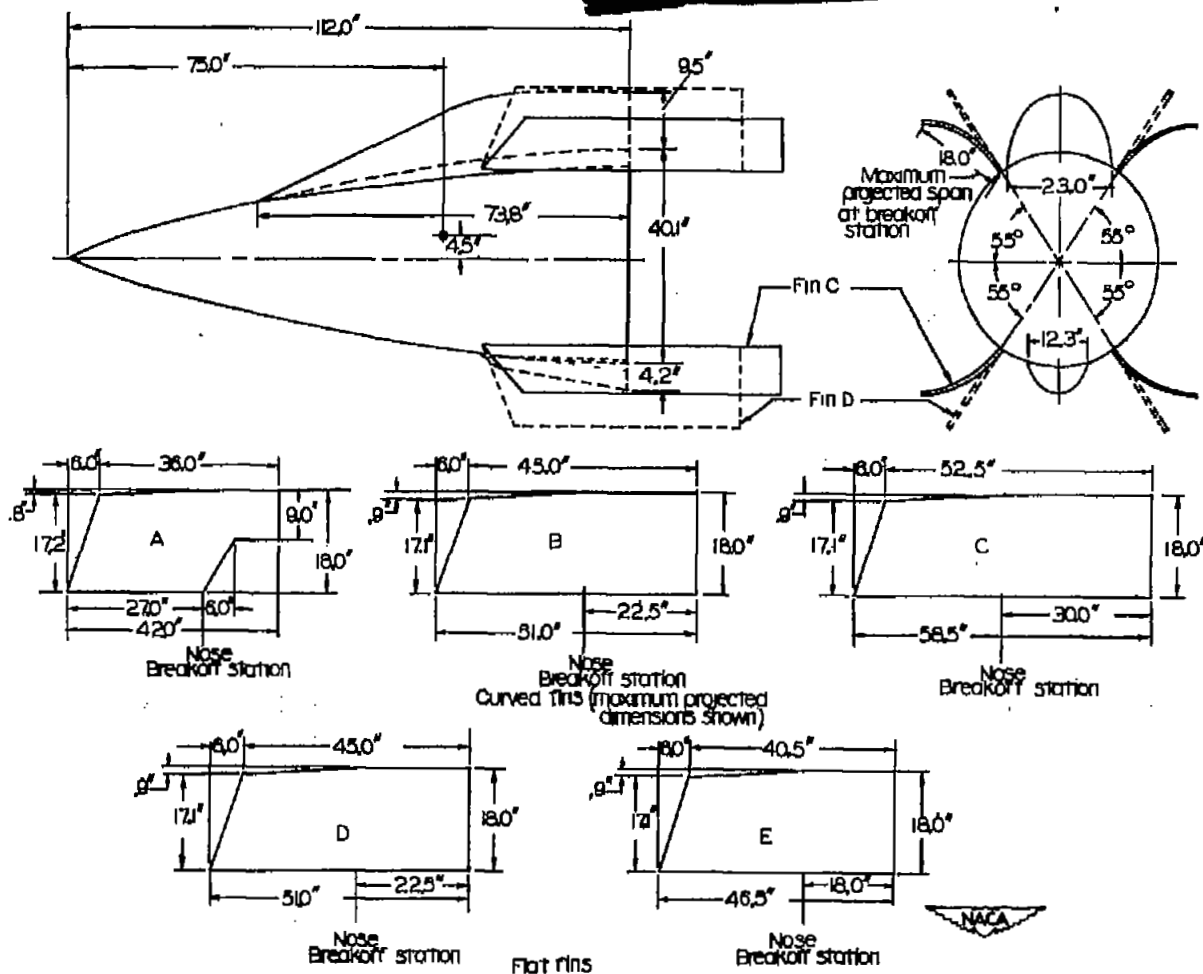
Figure 2.- Sketch of the $\frac{1}{15}$-scale model of the jettisonable nose section of the Bell X-2 airplane,
showing fin arrangements tested on the model. Curved fins (A, B, and C) were installed in a
manner similar to that shown for arrangement C (solid lines). Flat fins (D and E) were
installed in a manner similar to that shown for arrangement D (dashed lines). All dimensions
are full-scale values.

Reefed parachute

112" 20" 96" 160"

63.75"
38.25"

—Bridle lines —Extension line —Shroud lines

⊕ Attachment point

19"r
37° 37°
44° 44°

4-line bridle

25"
44° 44°
19"r

3-line bridle

25"
22"

2-line bridle

4.5"

1-line bridle

Figure 3.- Sketch of the $\frac{1}{15}$-scale model of the jettisonable nose section of the Bell X-2 airplane showing the various methods of attaching the parachutes. All dimensions are full-scale values.

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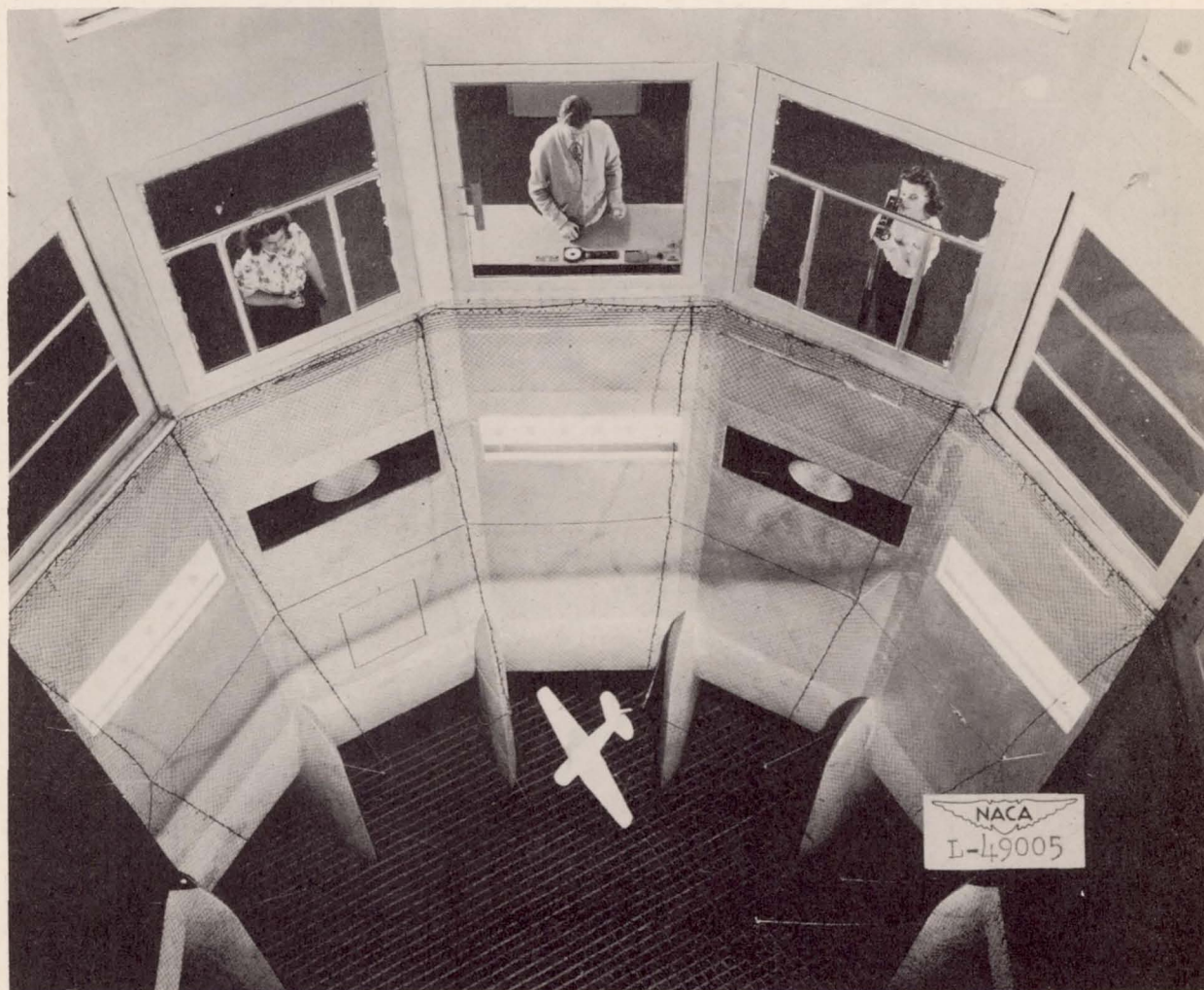
Figure 4.- Photograph showing the test section of the Langley 20-foot
free-spinning tunnel. A typical spin-tunnel airplane model is shown
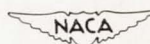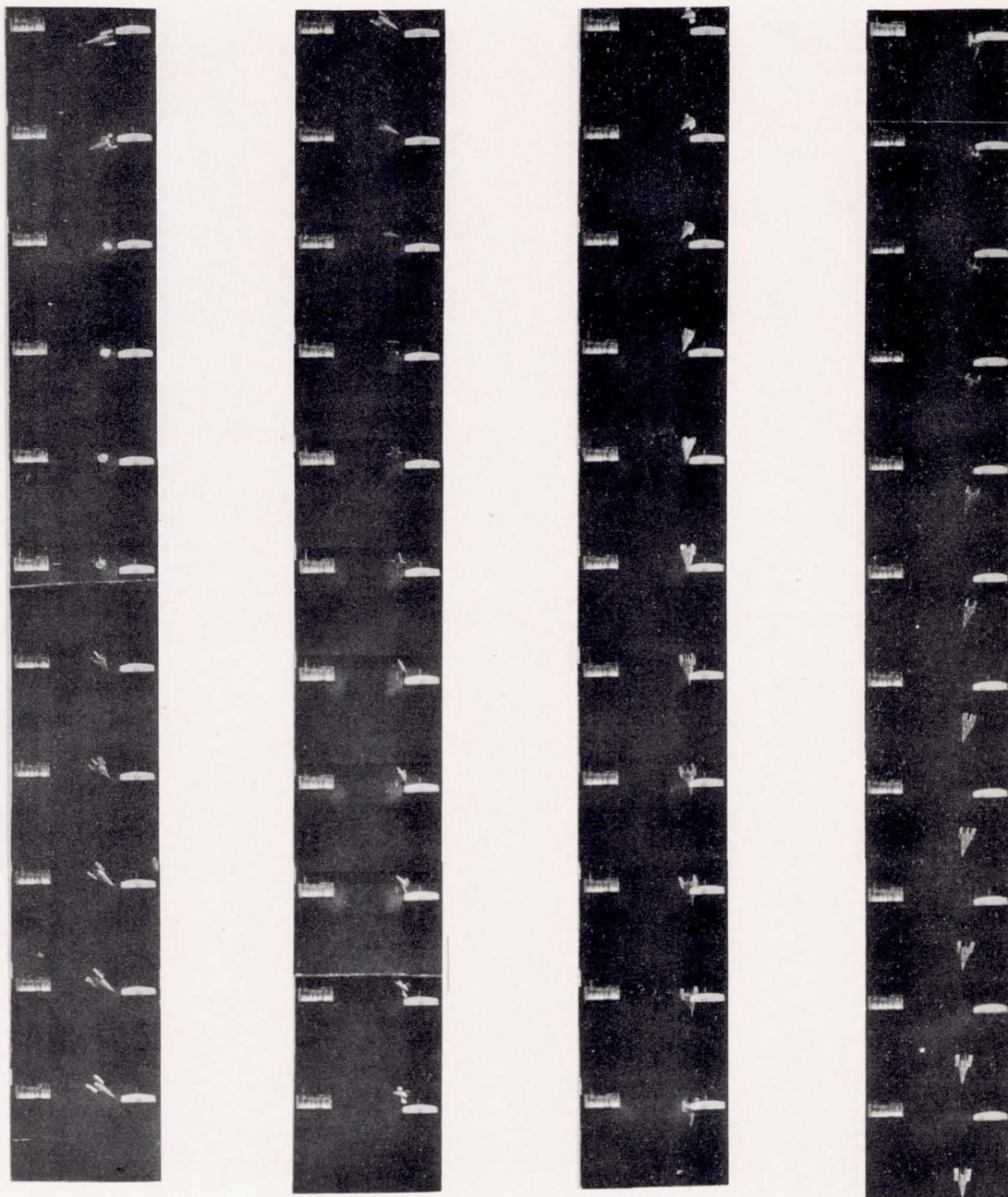spinning in the tunnel.   SECRET

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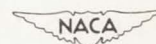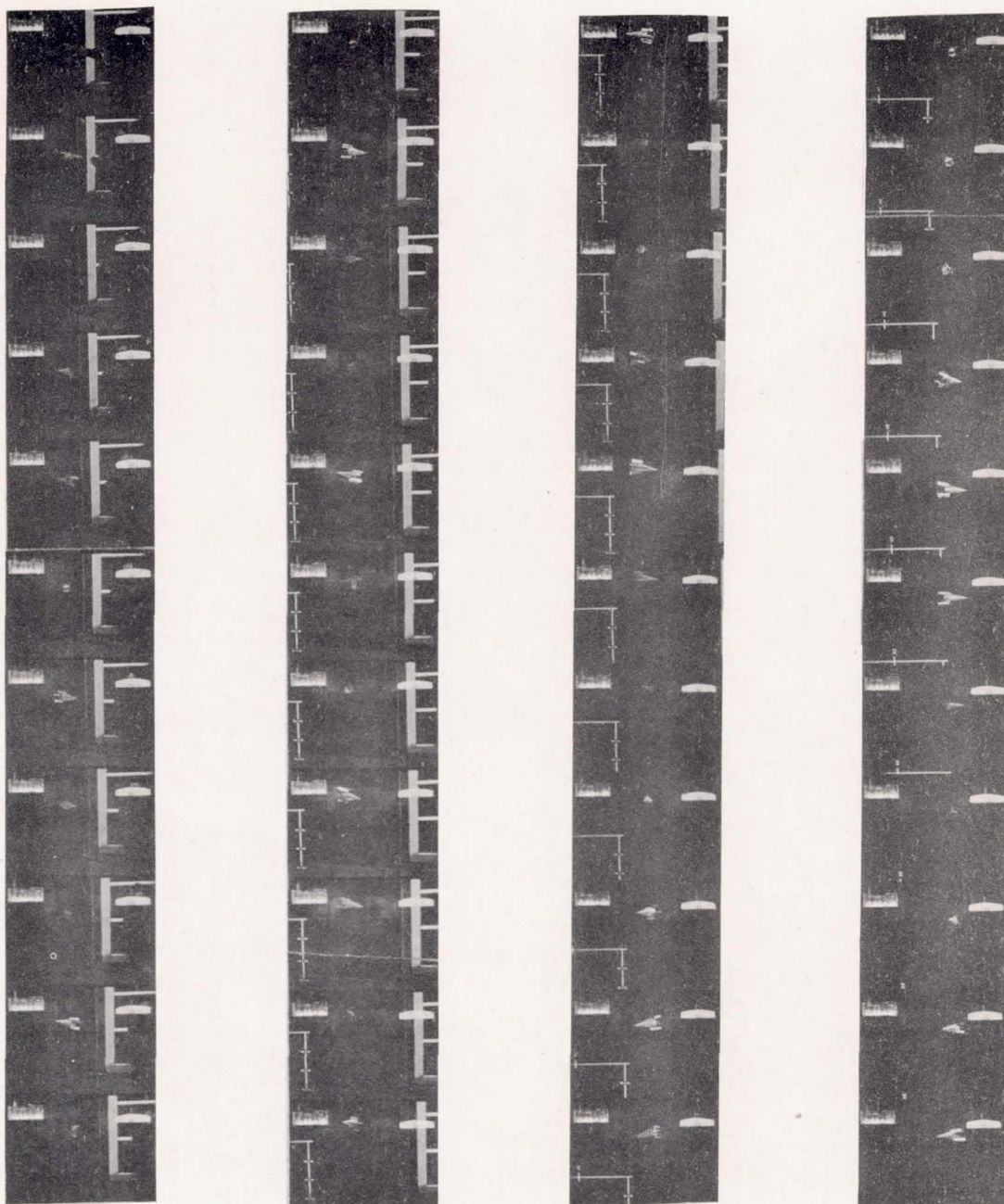
Figure 5.- Moving-picture strips of tests of the $\frac{1}{15}$-scale model of the jettisonable nose section of the X-2 airplane with fins C attached. The model is shown as it damped an applied rotation about a vertical wind axis and descended stably nose down. Camera speed was 32 frames per second.
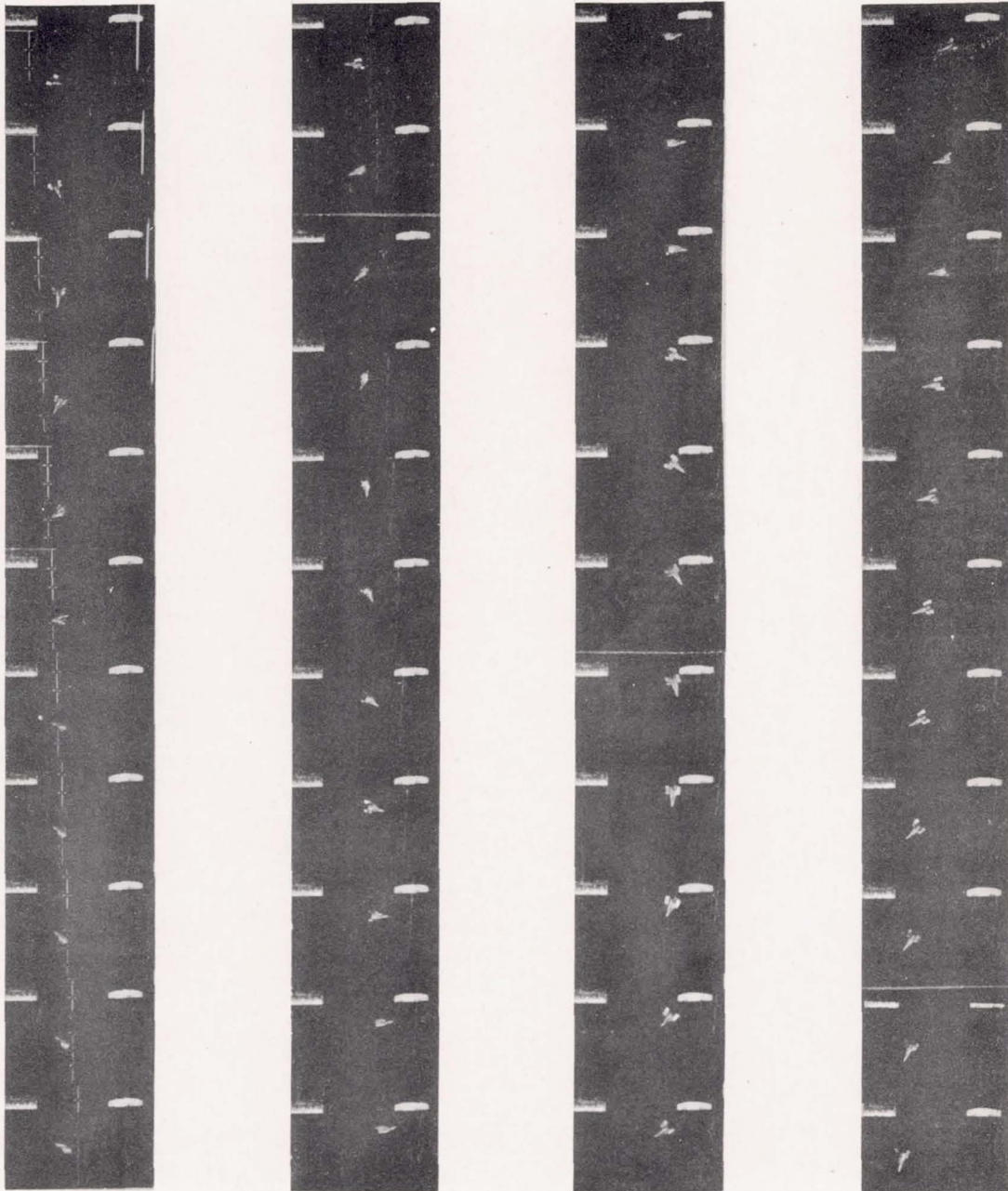
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Figure 5.- Concluded.
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Figure 6.- Moving-picture strips of tests of the $\frac{1}{15}$-scale model of the

jettisonable nose section of the X-2 airplane with fins B attached. The model is shown oscillating through an arc of approximately $\pm 90°$ from a nose-down attitude. Camera speed was 32 frames per second.

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ABSTRACT

A supplementary investigation on the stabilization of the jettisonable nose section of the X-2 airplane has been conducted in the Langley 20-foot free-spinning tunnel. It was found that the nose section could be stabilized by the addition of curved fins which could be folded against the fuselage for normal flight.